Confined Space Hazards

- The hazards encountered and associated with entering and working in confined spaces are capable of causing bodily injury, illness, and death to the worker.
- It should always be considered that the most unfavorable situation exists in every confined space and that the danger of explosion, poisoning, and asphyxiation will be present at the onset of entry.
- Before forced ventilation is initiated, information such as restricted areas within the confined space, voids, the nature of the contaminants present, the size of the space, the type of work to be performed, and the number of people involved should be considered.
- The ventilation air should not create an additional hazard due to recirculation of contaminants, improper arrangement of the inlet duct, or by the substitution of anything other than fresh (normal) air (approximately 20.9% oxygen, 78.1% nitrogen, and 1% argon with small amounts of various other gases).
- The terms air and oxygen are sometimes considered synonymous. However, this is a *dangerous* assumption, since the use of oxygen in place of fresh (normal) air for ventilation will expand the limits of flammability and increase the hazards of fire and explosion.

Types of Confined Spaces

- Confined spaces can be categorized generally as those with open tops and with a depth that will restrict the natural movement of air, and enclosed spaces with very limited openings for entry. (In either case, the space may contain mechanical equipment with moving parts.)
- Degreasers, pits, and certain types of storage tanks may be classified as open topped confined spaces that usually contain no moving parts. However, gases that are heavier than air (butane, propane, and other hydrocarbons) remain in depressions and will flow to low points where they are difficult to remove.
- Other hazards may develop due to the work performed in the confined space or because of corrosive residues that accelerate the decomposition of scaffolding supports and electrical components.
- Confined spaces such as sewers, casings, tanks, silos, vaults, and compartments of ships usually have limited access which increases the risk of injury.

Types of Confined Spaces (cont'd)

- Hazards specific to a confined space are dictated by:
  1. the material stored or used in the confined space; as an example, damp activated carbon in a filtration tank will absorb oxygen, thus creating an oxygen deficient atmosphere;
  2. the activity carried out, such as the fermentation of molasses that creates ethyl alcohol vapors and decreases the oxygen content of the atmosphere; or
  3. the external environment, as in the case of sewer systems that may be affected by high tides, heavier than air gases, or flash floods.
- The most hazardous kind of confined space is the type that combines limited access and mechanical devices. Digesters and boilers usually contain power-driven equipment which, unless properly isolated, may be inadvertently activated after entry.

Reasons for Entering Confined Spaces

- Usually done to perform a necessary function, such as inspection, repair, maintenance (cleaning or painting), or similar operations which would be an infrequent or irregular function of the total industrial activity.
- Entry may also be made during new construction. When the area meets the criteria for a confined space, all ventilation and other requirements should be enforced.
- One of the most difficult entries to control is that of unauthorized entry, especially when there are large numbers of workers and trades involved, such as welders, painters, electricians, and safety monitors.
- A final and most important reason for entry would be emergency rescue. The standby person and all rescue personnel should be aware of the structural design of the space, emergency exit procedures, and life support systems required.

Flammable Atmospheres

- Generally arise from enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of work, chemical reactions, concentrations of combustible dusts, and desorption of chemical from inner surfaces of the confined space.
- Flammable gases such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases or vapors from liquid hydrocarbons can be trapped in confined spaces, and since many gases are heavier than air, they will seek lower levels as in pits, sewers, and various types of storage tanks and vessels.
- In a closed top tank, lighter than air gases may rise and develop a flammable concentration if trapped above the opening.
- The byproducts of work procedures such as spray painting can generate flammable or explosive conditions within a confined space.
- Welding in a confined space is a major cause of explosions in areas that contained combustible gas.
- Combustible dust concentrations are usually found during the process of loading, unloading, and conveying grain products, nitrated fertilizers, finely ground chemical products, and any other combustible material.

Toxic Atmospheres

- The sources of toxic atmospheres encountered in confined spaces may arise from the following:
  1. The manufacturing process (for example, in producing polyvinyl chloride, hydrogen chloride is used as will as vinyl chloride monomer, which is carcinogenic).
  2. The product stored [removing decomposed organic material from a tank can liberate toxic substances, such as hydrogen sulfide (H_2S)].
  3. The operation performed in the confined space (for example, welding or brazing with metals capable of producing toxic fumes).
- During loading, unloading, formulation, and production, mechanical and/or human error may also produce toxic gases which are not part of the planned operation.
- Carbon monoxide (CO) is a hazardous gas that may build up in a confined space.
  - Odorless, colorless gas approximately the same density as air is formed from incomplete combustion of organic materials such as wood, coal, gas, oil, and gasoline; can be formed from microbial decomposition of organic matter in sewers, silos, and fermentation tanks.

Toxic Atmospheres (cont'd)

- Early stages of CO intoxication are nausea and headache. May be fatal at 1000 ppm in air, and is considered dangerous at 200 ppm, because it forms carboxyhemoglobin in the blood which prevents the distribution of oxygen in the body.
- A safe reading on a combustible gas indicator does not ensure that CO is not present. Carbon monoxide must be tested for specifically.
- The formation of CO may result from chemical reactions or work activities, therefore fatalities due to CO poisoning are not confined to any particular industry. Examples:
  - Sewage treatment plants due to decomposition products and lack of ventilation in confined spaces
  - Formation of silo gas in grain storage elevators

Irritant (Corrosive) Atmospheres

- Irritant or corrosive atmospheres can be divided into primary and secondary groups.
- The primary irritants exert no systemic toxic effects (effects on the entire body). Examples include chlorine, ozone, hydrochloric acid, hydrofluoric acid, sulfuric acid, nitrogen dioxide, ammonia, and sulfur dioxide.
- A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation. Examples include benzene, carbon tetrachloride, ethyl chloride, trichloroethane, trichloroethylene, and chloropropene.
- Irritant gases vary widely among all areas of industrial activity. They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations.
- Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation but may result in a general weakening of the defense reflexes from changes in sensitivity. The danger in this situation is that the worker is usually not aware of any increase in his/her exposure to toxic substances.

Asphyxiating Atmospheres

- The normal atmosphere is composed approximately of 20.9% oxygen, 78.1% nitrogen, and 1% argon with small amounts of various other gases.
- Decreased oxygen levels (below the atmospheric level of 20.9% by volume) can cause various effects including:
  - Level of 17%: increased breathing volume and accelerated heartbeat
  - Between 14-16%: increased breathing volume, accelerated heartbeat, very poor muscular coordination, rapid fatigue, and intermittent respiration
  - Between 6-10%: nausea, vomiting, inability to perform, and unconsciousness
  - Less than 6%: spasmatic breathing, convulsive movements, and death in minutes

Asphyxiating Atmospheres (cont'd)

- Reduction of oxygen in a confined space may be the result of either consumption or displacement.
- Consumption of oxygen:
  - Takes place during combustion of flammable substances, as in welding, heating, cutting, and brazing
  - During bacterial action, as in the fermentation process
  - During chemical reactions as in the formation of rust on the exposed surface of the confined space (iron oxide)
  - Rate of consumption influenced by the number of people working in a confined space and the amount of their physical activity
- Displacement of oxygen by another gas:
  - Examples of gases that are used to displace air, and therefore reduce the oxygen level, are helium, argon, and nitrogen. Carbon dioxide may also be used to displace air and can occur naturally in sewers, storage bins, wells, tunnels, wine vats, and grain elevators.
  - Gases such as nitrogen, argon, helium, and carbon dioxide are used as inerting agents to displace flammable substances and retard pyrophoric reactions, resulting in oxygen deficient atmospheres.

General Safety Hazards
Mechanical

- If activation of electrical or mechanical equipment would cause injury, each piece of equipment should be manually isolated to prevent inadvertent activation before workers enter or while they work in a confined space.
- To prevent vapor leaks, flashbacks, and other hazards, workers should completely isolate the space.
  - The closing of valves is not sufficient - all pipes must be physically disconnected or isolation blanks bolted in place.
  - Where flammable liquids or vapors may re-contaminate the confined space, the blanked or disconnected pipes should be inspected and tested for leakage.
- Other areas of concern are steam valves, pressure lines, and chemical transfer pipes.

General Safety Hazards
Communication Problems

- Communication between the worker inside and the standby person outside is of utmost importance.
- When visual monitoring of the worker is not possible because of the design of the confined space or location of the entry hatch, a voice or alarm-activated explosion proof type of communication system will be necessary.
- Suitable illumination of an approved type is required to provide sufficient visibility for work in accordance with the recommendations made in the Illuminating Engineering Society Lighting Handbook.

General Safety Hazards
Entry and Exit

- Entry and exit time is of major significance as a physical limitation and is directly related to the potential hazard of the confined space.
- The extent of precautions taken and the standby equipment needed to maintain a safe work area will be determined by the means of access and rescue.
- The following should be considered:
  - Type of confined space to be entered
  - Access to the entrance
  - Number and size of openings
  - Barriers within the space
  - Occupancy load
  - Time requirement for exiting in event of fire or vapor incursion
  - Time required to rescue injured workers

Physical Hazards
Thermal Effects

- When a body temperature of approximately 102F is exceeded, workers are less efficient, and are prone to heat exhaustion, heat cramps, or heat stroke.
- Special precautions must be taken in cold environments to prevent frostbite, trench foot, and general hypothermia.
- Protective insulated clothing for both hot and cold environments will add additional bulk to the worker and must be considered in allowing for movement in the confined space and exit time.

Physical Hazards
Noise

- Noise problems are usually intensified in confined spaces because the interior tends to cause sound to reverberate and thus expose the worker to higher sound levels than those found in an open environment.
- This intensified noise increases the risk of hearing damage to workers which could result in temporary or permanent loss of hearing.
- Noise in a confined space which may not be intense enough to cause hearing damage may still disrupt verbal communication with the emergency standby person on the exterior of the confined space.

Physical Hazards
Vibration

- Whole body vibration may affect multiple body parts and organs depending upon the vibration characteristics.
- Segmental vibration, unlike whole body vibration, appears to be more localized in creating injury to the fingers and hands of workers using tools, such as pneumatic hammers, rotary grinders or other hand tools which cause vibration.

Physical Hazards

General/Physical

- Some physical hazards such as scaffolding, surface residues, and structural hazards cannot be eliminated because of the nature of the confined space or the work to be performed.
- The use of scaffolding in confined spaces has contributed to many accidents caused by workers or materials falling, improper use of guard rails, and lack of maintenance to insure worker safety.
- Surface residues in confined spaces can increase the already hazardous conditions of electrical shock, reaction of incompatible materials, liberation of toxic substances, and bodily injury due to slips and falls. Without protective clothing, additional hazards to health may arise due to surface residues.
- Structural hazards within a confined space such as baffles in horizontal tanks, trays in vertical towers, bends in tunnels, overhead structural members, or scaffolding installed for maintenance constitute physical hazards, which are exacerbated by the physical surroundings.
- Rescue procedures may require withdrawal of an injured or unconscious person. Careful planning must be given to the relationship between the internal structure, the exit opening, and the worker.